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DISCUSSION OF ECONOMIC EFFECTS OF RESERVOIR SEDIMENTATION

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By T. Blench, Martin Maevers, and William E. Corfitzen

HYDRAULICS DIVISION

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Technical Division	*Proceedings-Separate Number*
Air Transport	42, 43, 48, 52, 60 (Discussion: D-XXVIII, D-7, D-16, D-23, D-18)
City Planning	58, 60, 62, 64 (Discussion: D-16, D-23)
Construction	43, 50, 55, 71 (Discussion: D-3, D-8, D-23, D-17, D-40)
Engineering Economics	46, 47, 62, 64, 65, 68, 69 (Discussion: D-2, D-19, D-27, D-30)
Engineering Mechanics	41, 49, 51, 54, 56, 59, 61, 88, 89 (Discussion: D-5, D-XXIII, D-XXV, D-18, D-24, D-33, D-34)
Highway	43, 44, 48, 58, 70 (Discussion: D-XXVIII, D-7, D-16, D-23, D-13)
Hydraulics	50, 55, 56, 57, 70, 71, 78, 79, 80, 83, 86 (Discussion: D-XXVII, D-9, D-11, D-19, D-28, D-29)
Irrigation	46, 47, 48, 55, 56, 57, 67, 70, 71, 87, 88 (Discussion: D-XXIII, D-3, D-7, D-11, D-19, D-25-K, D-29, D-17, D-30, D-38, D-40)
Power	48, 55, 56, 69, 71, 88 (Discussion: D-XXIII, D-2, D-3 D-7, D-11, D-19, D-25-K, D-17, D-30, D-38, D-40)
Sanitary Engineering	55, 56, 87 (Discussion: D-10, D-29)
Soil Mechanics and Foundations	43, 44, 48 (Discussion: D-4, D-XXVIII, D-7)
Structural	42, 49, 51, 53, 54, 59, 61, 66, 89 (Discussion: D-5, D-3, D-8, D-16, D-23, D-13, D-21, D-24, D-25-K, D-32, D-17, D-33, D-34)
Surveying and Mapping	50, 52, 55, 60, 63, 65, 68
Waterways	41, 44, 45, 50, 56, 57, 70, 71 (Discussion: D-XXVII, D-9, D-8, D-19, D-27, D-28)

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DISCUSSION

T. BLENCH,[2] M. ASCE.—Experience in India makes the writer see this paper not as a study in economics but as a statement of some of the unforeseen, but foreseeable, consequences of interfering with sediment-bearing rivers of regime type. In India, British engineers began interfering with such rivers at the end of the nineteenth century. As they built nothing higher than diversion dams, they learned about river regime at small cost. From experience with canal systems (after some forty years of expensive fighting against nature) they established the basic laws of regime behavior. After about fifty years, these engineers conducted the world's largest quantitative investigation of water-logging and alkali formation but only when, in the area investigated, land was turning alkaline at the rate of about 25,000 acres annually. Not until 1947—on a motion by the writer—did the Central Board of Irrigation (Government of India) Research Committee resolve that soil conservationists should be associated on equal terms with engineers as soon as a project was contemplated on a sediment-bearing river. Apparently the acquisition of vital knowledge, so simple in retrospect, is a slow and expensive process.

There seems no reason in these days why expert knowledge should not be used to prevent projects from being conceived in ignorance of possible ill effects. The Soil Conservation Service, United States Department of Agriculture, has published information on the effects of soil mismanagement and sedimentation damage, and that agency knows the practical ways of attacking the trouble at its source. The technique of measuring sediment load in streams has been developed mainly in the United States and is satisfactory. Agricultural experts in Canada and the United States are fully acquainted with the physics of the alkali problem, and experience with alkali formation on irrigation projects in India is extensive and practical. Hydrologists know the principles of making soil-water inventories.

In India, regime theory has been in use since the late ninteen twenties to estimate and explain the behavior of regime-type rivers after interference. Publications have appeared at intervals in Europe and India; yet with all this information in existence the author has to draw engineers' attention to: (1) The aggradation that experts know must occur upstream; (2) the degradation that must occur downstream; and (3) the consequences of reservoirs becoming dwindling assets and perhaps irreplaceable assets. With justice, he might have added items such as published misapprehensions about the unlikelihood of alkali formation, uncontrolled withdrawals from the water table, danger of waterlogging in some areas, and water-table depletion in others due to control of river discharges.

The author is to be congratulated on clarifying some of the important points that should be considered at the inception of a project.

NOTE.—This paper by William E. Corfitzen was published in August, 1950, as *Proceedings-Separate No. 30.* The numbering of footnotes in this Separate is a continuation of the consecutive numbering used in the original paper.

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MARTIN MAEVERS[3].—An interesting summary of the study made by the Subcommittee on Economic Effects of Reservoir Sedimentation has been presented.

The committee is concerned with the short life of the large number of reservoirs which have been created since 1925 and those which are to be constructed for water supply, irrigation, power, and flood control in the future. The author describes the losses to individuals and society that occur from sedimentation of a reservoir: reduced farm income, loss to families with derivative income from irrigation farming, decline of land values, crop failures, loss of undepreciated investment, loss of taxes, and many more.

The question may well be asked, "Are these really losses in the true sense of the word?" Losses can be caused only by forces either unforeseen or forces whose occurrence is a matter of probability. However, sedimentation of reservoirs is a known factor, and its occurrence can be calculated within the limits of our ability to determine the sedimentation rate.

If these so-called losses were to be avoided when planning a particular reservoir with a given sedimentation rate, allowance would have to be made for: (1) A declining income stream from the land; (2) amortization of farm and industrial investment during the life of the reservoir; (3) a slow emigration of population and capital (amortization funds) as the services of the reservoir decline.

If the benefits from the services of the reservoir under these conditions are greater than the cost, the construction of the dam would be justified from a short-run point of view.

It is doubtful, however, that people who approve expenditures for large irrigation, power, or flood-control projects have such a short-run view in mind. It is equally doubtful that the planning engineers think in those terms, or they would not talk about "damages" from sedimentation of reservoirs.

With the development of any plan for dam construction, therefore, it must be decided in advance whether the economy created or protected by the services of the reservoir should be temporary or permanent.

What are the considerations that enter into the cost of furnishing a permanent service?

They are: (1) The probable rate of sedimentation. The source of sedimentation must be known, whether it can be reduced, by what means and by how much, and whether such reductions are temporary or permanent. A primary consideration, therefore, must be the condition of the watershed and the cost of reducing erosion to a point where long-time operation of the planned reservoir is possible; (2) the cost of the dam and appurtenant works; (3) the cost of maintenance of reservoir space for sediment which cannot be controlled upstream; (4) possible damage caused downstream of the dam because of its construction. This would include channel deterioration due to shifting of sediment from below the dam to downstream areas not threatened now by flood damage. It would include damage to land adjoining the river downstream from the dam, caused by lowering or raising of the water table and beach-erosion damage due to reducing the normal supply of sand to the sea.

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All of these costs enter into the expenditures for constructing a dam. All of them are calculable factors. And all of these costs must be repaid from the services which the reservoir furnishes.

Objection is often raised to this approach in that it requires projection of events too far into the future, and "Who can look into the seeds of time and say which grain will grow and which will not?" Actually, it is not required to look into the distant future; but a complete plan which includes all factors within the present knowledge of things must be laid out. For instance, it is known that a reservoir will silt up and that the rate of sedimentation can be estimated. Provision will have to be made for substitute space, or for cleaning of the reservoir, or for building upstream barriers, or for taking the upstream watershed out of use. It can be estimated when such measures have to be undertaken and what their cost will be. This has to be included in a complete plan. Such a plan must be tentative in some of its phases, because some of the proposed measures will not require installation until many years have passed, when the thoughts of today will have given way to new ideas, developments, and inventions. To avoid taking all the benefits for our present generation and burdening the future with the enormous cost of either providing debris control or abandoning the project, a complete plan must be worked out.

Some of the project plans, like watershed land improvement and channel stabilization in areas above the proposed dam or dams, have to be undertaken first. Cover improvements should be undertaken well in advance of construction because they require time to become effective. The cost of these measures should be counted at compound interest to the day the services from the reservoirs become available. And the cost of those measures that are to be constructed well in the future must be discounted to the date the reservoir services become available. To be comparable all costs should be expressed in terms of deflated dollars.

Against these costs must be balanced the benefits. It is important that the benefits be expressed in terms of net returns. Only then is it possible to judge whether or not the investments are beneficial to society. A misinvestment today diverts funds not only from more profitable present investment opportunities but also reduces the availability of funds for investment at a future day. Misinvestments of today depress the future potential standard of living of the nation.

All secondary benefits, sometimes called "contributions to the national income," must be excluded when comparing benefits with cost of a specific project. The first and essential point in the benefit-cost analysis is to find out whether the investments made in the project pay for themselves at a rate comparable to investments made in the open market. Secondary benefits accompany any large investments. They, therefore, only enter into consideration when it must be decided which of two investment opportunities with equal primary benefits to choose.

The planning and analysis of river basin developments should lead to recommendations of two types of projects. The first represents construction that should be termed temporary. It would generally be exploitative. It would allow not only for repayment of the cost of the dams but also complete

amortization of investments in the development area served by the reservoir. The second would allow a permanent development which would add throughout time to the net national income.

Present planning and analysis is mostly made on the basis of repayment or amortization of the dam itself. But this evades the main consideration, which is the amortization or permanency of the economy developed by the reservoir services. It is only when this is not taken into consideration that reservoir sedimentation can be called "damages." After having built the dams and justified their construction by proving that the services they render would pay for the structures over a given period of years, it is realized that reservoirs fill up with sediment, and the question arises as to what to do with the economy created because of them. The economy having been created, remedial measures must be designed to perpetuate the services of the reservoirs.

The result of evaluating remedial measures for existing dams may lead to these conclusions: It may be found that a plan for perpetuating the services of a reservoir will render enough benefits to justify its execution or that the cost of a remedial plan is less than the cost to liquidate the economy created by the original dam.

In the first case the plan provides a true benefit to society; in the second case it minimizes the loss to society.

WILLIAM E. CORFITZEN,[4] M. ASCE.—The number of publications available on this subject has been emphasized by Mr. Blench, who states that with all the information available, engineers' attention must be drawn to certain fundamental aspects of the problem. This was particularly interesting as the same thought was expressed in at least three of the discussions presented in 1949 by the ASCE Hydraulics Division in the symposium of the Joint Committee on Design and Operation of Multiple Purpose Reservoirs.[5]

Considering the earlier basic studies, such as those of the British engineers in India and the more recently published data on the subject (which were probably collected more scientifically), it seems likely to the writer that available technical information is still of greater interest to the research man than to the practicing engineer. Perhaps there yet remains a zone where more printed information is required in simplified form relating to the application of what the research men have found.

It must be recognized, however, that there can be no clear-cut approach to the solution of the sedimentation problems of any given stream. So many factors are involved, and such an infinite combination of those factors exists, that each stream presents a special problem that must be studied in detail. In this connection the writer recalls the sedimentation studies conducted on the lower Colorado River prior to the construction of Imperial Dam and desilting works. Sedimentation was a new field to most of the engineers working on the problem, and it was their hope that the early studies of the British engineers in India would provide a ready answer. However, application of the formulas developed for conditions there did not furnish results which

[4] Reclamation Specialist, ECA, U. S. Embassy, Rome, Italy.

[5] "Multiple-Purpose Reservoirs, A Symposium," *Transactions*, ASCE, Vol. 115, 1950, p. 789.

checked observations of conditions found in the field. It was realized soon, however, that the Indian studies were of infinite help in pointing the way toward research of local significance and in helping the investigators to avoid many pitfalls. Mr. Blench has hit a keynote with which the writer agrees completely—that soil conservationists should be associated on equal terms with engineers as soon as a project is contemplated on a sediment-bearing river. In their studies of natural phenomena engineers have become so highly specialized and involved in the complexities of their own fields that they often neglect to coordinate these jobs as fully as they should be coordinated. There really is no reason why this should happen but the fact remains that it does. It behooves the engineer associated with such problems to make certain that he has called upon all experts whose services may have some bearing on the solution of the sedimentation problem.

Mr. Maevers has presented some interesting thoughts that should be kept in mind during the planning stages of reservoirs. It is clear that, although economists and engineers may use a different language, they intend to express the same concept. In his professional contacts with Europe, the Middle East, and Africa, the writer has become acutely aware of the need for watershed control. In many of the so-called "depressed areas" of the world, plans are being made for economic development, either through local resources or with United States assistance under the "Point IV Program."[6]

Regardless of their location, engineers are generally eager to approach their problems realistically and to understand the limitations of any proposal. Unfortunately, there are many outside the engineering fold who think of irrigation and power development as an easy cure-all for the economic ills of these depressed areas. As mentioned by Mr. Blench, there is danger that many projects will be proposed and constructed, involving millions of dollars, without reference to the large amount of technical data that are already available on this subject. Also deplorable is the fact that little or nothing is being done, in many of the depressed areas, to collect basic data, such as rainfall, temperature, wind velocity, and soils data, which would be useful in solving the problems that engineers know must be solved before engineering structures can be constructed safely and economically. Both the discussions serve to focus attention on the value and need of watershed control. Soil conservationists, engineers, and foresters must be brought closer together during the formulation of plans for these large reservoirs if they are to be constructed to render maximum service adequately and economically.

[6] *Public Law 535, Section 401*, 81st Congress, June 5, 1950.

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